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ASBESTOS DISEASE IN MAINTENANCE WORKERS OF THE CHEMICAL INDUSTRY*

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Clinical field examinations of several large groups of workers in various plants the chemical industry, undertaken by our laboratory during the past few years, ha revealed the frequency of chest x-ray abnormalities (small irregular opacities and/ pleural changes) of the type known to be induced by dust exposure. Chest x-rays workers of three vinyl chloride polymerization plants,[1,2] a styrene polymerizati plant,[3] a titanium dioxide-manufacturing plant,[4] and a dye-manufacturing plant we read without knowledge of age, past medical history, occupational history, or findin on physical examination. Yet, when parenchymal changes (irregular or round opacities) and/or pleural changes (thickening or calcification) were found, possil exposure to asbestos, silica, or coal dust had usually occurred.

It had been our practice when examining workers from chemical plants to exerc special effort to include maintenance personnel, because it is well known that su work may often involve significant overexposure to toxic substances, especially wh repair becomes urgently necessary.

In 1971, reports by Bittersohl and Ose had called attention to asbestos hazards the chemical industry.[5,6] Twenty-six cases of mesothelioma had been observed ove period of 4 years (1967–71); the number of cases was in sharp contrast with t extreme rarity of this type of malignancy in the preceding period. Twenty-two patie had worked in a large chemical industry (Leuna), two in another chemical pl (Buna), and one in a foundry. The only female patient had not experienced a occupational exposure to asbestos, but she was the wife of a worker at the Leuna pla Only 16 patients had experienced direct occupational exposure to asbestos, while n patients had been subjected to indirect exposure (working in areas where asbestos v occasionally handled by other workers); in one case, there was a history of o household exposure. Chest x-ray films obtained prior to the development of mesot lioma were available in 23 cases; in 17 patients pleural thickening and pleural plaq were present.

It was known that extensive insulation work had taken place in several depa ments of the Leuna chemical plant in the early 1950s. Large amounts of asbestos l been used, and evidence for high concentrations of airborne fibers in the past v available. In these production areas and in adjacent shops, asbestos exposure v consequently a consideration for all workers, not only for those installing r insulation or removing old material. Maintenance work was thought to involv special risk. Other sources of asbestos exposure, identified in the second chemi plant, were fire-resistant protective equipment used by welders and the manipulat of insulation with repair work on pipes.

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TABLE 1
AGE DISTRIBUTION OF 185 MAINTENANCE WORKERS

Age (years)									
20–29.9		30–39.9		40–49.9		50–59.9		60+	
Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
27	15	18	10	34	18	85	46	21	11

POPULATION AND METHODS

To obtain information concerning the potential dimensions of asbestos hazards among workers of the chemical industry, a cross-sectional investigation of maintenance workers of a large chemical plant in New Jersey was undertaken.

All workers were volunteers and represented about half of the men in maintenance categories in the plant (welders, carpenters, electricians, pipefitters, etc.). We deliberately sought to include as many men as possible who had terms of employment of more than 10 years; we examined only a sample of employees with shorter durations of exposure. The age distribution and the figures for duration since onset of exposure of the group are given in TABLES 1 and 2. Twenty-six percent of those examined had worked less than 10 years and 59% had worked more than 20 years since first exposure.

The examination protocol included a lifetime occupational history, past medical history, smoking history, British Medical Research Council respiratory questionnaire, complete physical examination, standard 14 × 17-in. posteroanterior chest x-ray film, and pulmonary function tests (spirometry and maximal expiratory flow volume curves).

Chest x-ray films were read in consensus by four physicians experienced in occupational lung disease who had no knowledge of the past medical history, occupational history, respiratory symptoms, or findings on physical examination; the films were categorized according to the ILO U/C Classification of Radiographs of Pneumoconioses. Results of pulmonary function tests [forced vital capacity (FVC), forced expiratory volume 1 sec (FEV_1) and forced expiratory flow over the mid-FVC (FEF_{25-75})] were compared to the predicted values of Morris *et al.*[7] without knowledge of the occupational history, radiologic findings, or findings on physical examination.

RESULTS

Radiologic Findings

Small irregular opacities, mostly in the lower lung fields but sometimes extending to the middle lung fields, of the type seen with parenchymal interstitial fibrosis, were present in 24% of those examined; in 10% of patients, these opacities were the only abnormality (TABLE 3).

Pleural thickening and calcification (with or without thickening) in 10% and 4% of cases, respectively, were found in the absence of definite radiologically evident parenchymal abnormalities; 14% of patients examined had pleural abnormalities only. In another 14%, both parenchymal and pleural changes were seen. The overall prevalence of parenchymal and/or pleural abnormalities consistent with asbestos-induced changes was 38%.

As expected, the prevalence of all chest x-ray abnormalities was higher in workers with more than 20 years exposure since onset of work (TABLE 4); pleural changes were a more frequent abnormality in the group than were parenchymal changes.

TABLE 2
DURATION SINCE ONSET OF FIRST ASBESTOS EXPOSURE

<10 Years		10–19.9 Years		20–29.9 Years		30+ Years	
Number	Percent	Number	Percent	Number	Percent	Number	Percent
49	26	27	15	41	22	68	37

TABLE 3
CHEST X-RAY ABNORMALITIES CONSISTENT WITH ASBESTOS-INDUCED CHANGES (PARENCHYMAL AND PLEURAL) IN (N = 185) MAINTENANCE WORKERS CHEMICAL PLANT

Radiologic Change (ILO U/C)	Number	Percent
None		
0/0–0/1	115	62
Parenchymal changes, total	45	24
1/0–1/2	42	22.4
2/1–2/3	3	1.6
3/2–3/4	0	—
Parenchymal changes only	19	10
Pleural changes, total	51	28
Pleural thickening only	18	10
Pleural calcification (with or without thickening)	7	4

TABLE 4
DURATION SINCE ONSET OF ASBESTOS EXPOSURE AND CHEST X-RAY CHANGES IN MAINTENANCE WORKERS (N = 185)

	Less Than 20 Years (n = 77)		More Than 20 Years (n = 108)	
Radiologic Changes	Number	Percent	Number	Percent
Normal (0/0–0/1)	66	86	49	45
Parenchymal changes, total	9	12	36	33
1/0–1/2	8	10	34	31
2/1–2/3	1	1	2	2
3/2–3/4	0	—	0	—
Parenchymal changes only	8*	10	11	10
Pleural changes, total	3	4	48	44
Pleural thickening only	1	1	17	16
Pleural calcification (with or without thickening, without parenchymal changes)	1	1	6	6

*See TABLE 6.

TABLE 5

CHEST X-RAY ABNORMALITIES CONSISTENT WITH ASBESTOS-INDUCED CHANGES (PARENCHYMAL AND PLEURAL) IN CHEMICAL PLANT MAINTENANCE WORKERS WITH NO PREVIOUS ASBESTOS EXPOSURE (N = 140)

Radiologic Change (ILO U/C)	Number	Percent
None		
0/0–0/1	90	64
Parenchymal changes, total	34	24
1/0–1/2	31	22
2/1–2/3	3	2
3/2–3/4	0	—
Parenchymal changes only	12	9
Pleural changes, total	38	27
Pleural thickening only	14	10
Pleural calcification (with or without thickening)	2	1

Careful analyses of life-long occupational histories recorded for all 185 maintenance workers revealed that in 140 of them, there had been no previous specific, defined occupational or nonoccupational dust exposure. In 45 workers, asbestos exposure, ranging from minimal to significant, had occurred in the past, preceding employment in the chemical plant.

Among those considered to have experienced significant previous exposure were workers who had been employed in an asbestos-manufacturing plant, had been active as pipe fitters or pipe coverers, had worked in brake maintenance and repair, or had participated in boiler repair work. Those considered to have been subjected to minor previous exposure included workers involved in spackling, shingle trimming, brake

TABLE 6

DURATION SINCE ONSET OF ASBESTOS EXPOSURE AND CHEST X-RAY CHANGES IN MAINTENANCE WORKERS WITH NO PREVIOUS ASBESTOS EXPOSURE (N = 140)

	Less Than 20 Years (n = 61)		More Than 20 Years (n = 79)	
Radiologic Changes	Number	Percent	Number	Percent
Normal (0/0–0/1)	54	89	36	46
Parenchymal changes, total	6	10	28	35
1/0–1/2	5	8	26	33
2/1–2/3	1	2	2	3
3/2–3/4	0	—	0	—
Parenchymal changes only	4*	7	8	10
Pleural changes, total	3	5	35	44
Pleural thickening only	1	2	13	16
Pleural calcification (with or without thickening, without parenchymal changes)	0	—	2	3

*Parenchymal changes (only) was the only radiologic abnormality with significantly higher prevalence in workers with previous asbestos exposure (χ^2 = 4.63; $p <$ [illegible]).

TABLE 7

PREVALENCE OF RESPIRATORY SYMPTOMS IN MAINTENANCE WORKERS (N = 185)

			Abnormal Chest X-Ray					
	Normal Chest X-Ray (n = 115)		Parenchymal Only (n = 19)		Pleural Only (n = 25)		Parenchymal and Pleural (n = 26)	
Symptoms	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Shortness of breath	19	17	2	11	4	16	11	42
Wheezing	27	23	5	26	6	24	7	27
Chronic bronchitis	20	17	3	16	7	28	6	23

repair (minimal, intermittent), and, in one case, residence in the neighborhood (two blocks away from) of an asbestos product-manufacturing plant.

A separate analysis was made of workers without any (even minimal) known preexisting asbestos exposure. When comparing the results with those obtained for the entire group of 185 workers, it was found that the prevalence of radiologic abnormalities, both parenchymal and pleural, was almost identical (TABLE 5).

The relationship between radiologic abnormalities and duration since onset of exposure (TABLE 6) was very similar in the group of 140 maintenance workers without any previous known asbestos exposure to that found in the total group of 185 workers examined (TABLES 4 & 6); there was no statistically significant difference in prevalence of parenchymal or pleural changes.

Clinical Findings: Symptoms and Signs

The only symptom reported with a higher frequency in workers with radiologic abnormalities was dyspnea on exertion (in those with both parenchymal and pleural changes; TABLE 7). Cough and sputum production consistent with a diagnosis of chronic bronchitis (TABLE 8) were found in 20% of workers examined. The difference in prevalence between current smokers and individuals who had never smoked regularly was not significantly different (22% vs 14%).

Abnormalities on physical examination were infrequent; rales were present mostly in persons with pleural changes. Clubbing and rales were detected in several cases with negative chest x-rays, raising the question of parenchymal fibrosis not yet radiologically detectable (TABLE 9).

TABLE 8

PREVALENCE OF CHRONIC BRONCHITIS IN CHEMICAL PLANT MAINTENANCE WORKERS

Smoking Habit	Total Number Examined	Chronic Bronchitis (MRC)	
		Number	Percent
Present smoker	67	15	22
Ex-smoker	75	15	20
Never smoked	42	6	14
Total*	184	36	20

*E[illegible]ding one subject for whom no smoking history was recorded.

TABLE 9

OBJECTIVE CHANGES ON PHYSICAL EXAMINATION IN 185 MAINTENANCE WORKERS

Abnormalities on Physical Examination	Normal Chest X-Ray (n = 115)		Abnormal Chest X-Ray: Parenchymal Changes Only (n = 19)		Abnormal Chest X-Ray: Pleural Changes Only (n = 25)		Abnormal Chest X-Ray: Both Parenchymal and Pleural Changes (n = 26)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Clubbing	7	6	0	—	1	4	1	4
Rales	8	7	0	—	3	12	3	12
Cyanosis	1	1	0	—	1	4	1	4
Increased AP diameter	4	3	0	—	1	4	5	19
Decreased breath sounds	6	5	1	5	0	—	4	15
Decreased heart sounds	3	3	2	11	2	8	1	4
Wheezing and/or rhonchi	7	6	1	5	2	8	1	4
P II > A II	6	5	1	5	3	12	2	8

Results of Pulmonary Function Tests

Pulmonary function tests (TABLE 10) indicated a relative low prevalence of restrictive dysfunction (5% of cases), probably related to the small number of cases with advanced parenchymal fibrosis.

An obstructive pattern was more often found and was, as expected, more prevalent in current and ex-smokers. The finding of a lower than normal FEV_1/FVC ratio in 17% of maintenance workers with a negative smoking history suggests that dust,

TABLE 10

PULMONARY FUNCTION ABNORMALITIES, RESTRICTIVE AND OBSTRUCTIVE PATTERN, IN CHEMICAL PLANT MAINTENANCE WORKERS

	Current Smoker (n = 67)		Ex-smoker (n = 75)		Never Smoked (n = 42)		Total (n = 184)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Restrictive dysfunction, FVC ≤ 79% of predicted	2(1)*	3	6(3)*	8	2	5	10	5.4
Obstructive dysfunction, FEV_1/FVC ≤ 74% (only)	6†	9	10	13	7	17	23	12.5
FEF_{25-75} ≤ 67% of predicted (only)	0	—	1	1	0	—	1	0.5
Both abnormalities	12	18	17	23	0	—	29	15.7
Total obstructive dysfunction	18	27	28	37	7‡	17	53	28.7

*Figures in parentheses denote mixed ventilatory dysfunction, predominantly restrictive.

†Tests incomplete in two subjects (FEF_{25-75} not available).

‡Difference in prevalance of obstructive dysfunction between current s[illegible]s and nonsmokers not statistically significant (χ^2 = 1.52; p = 0.25).

TABLE 11

CHEST X-RAY ABNORMALITIES IN CHEMICAL PLANT MAINTENANCE WORKERS

	Number	Abnormal Chest X-Ray: Number	Abnormal Chest X-Ray: Percent
Direct asbestos exposure (>5 years)	41	20	49
Direct asbestos exposure ("minor," intermittent, <5 years)	36	17	47
No direct asbestos exposure ("bystander")	108	33	30

irritant fumes, and gases in an industrial environment may have an adverse effect on respiratory function.

DISCUSSION

While in this group of maintenance workers chest x-ray abnormalities were relatively frequent, with pleural changes more prevalent than parenchymal fibrosis, subjective symptoms and pulmonary function abnormalities were much less prominent. This constellation of changes has been found to be rather characteristic for relatively less intense asbestos exposure. While progression to severe disabling parenchymal asbestosis is less probable under such circumstances, the risk for lung cancer and mesothelioma remains.

The chemical plant maintenance workers examined had experienced various degrees of asbestos exposure; while some of them had been subjected to direct and continuous asbestos exposure for periods of time longer than 5 years, others had had direct, but intermittent, exposure for shorter periods of time. More than half of those examined had never been directly engaged in work with asbestos; nevertheless, they had been present in areas where such work was performed by others (TABLE 11). A list of some of the job designations included in this last category is given in TABLE 12.

The prevalence of radiologic changes was higher in workers with direct asbestos

TABLE 12

MAINTENANCE WORKERS: OCCUPATIONS WITHOUT DIRECT HANDLING OF ASBESTOS

Laborer
Stockman
Area mechanic
Sheet metal mechanic
Mechanic helper
Maintenance helper
Millwright
Repairman
Pipefitter
Production worker

exposure. Nevertheless, it was considerable (30%) even in those with indirect asbestos exposure.

Comparative analysis of the entire group of 185 chemical plant maintenance workers, and of the 140 subjects without any previous asbestos exposure, yielded interesting results: prevalences of radiologic abnormalities (both parenchymal and pleural) were almost identical. The relationship between prevalence of radiologic abnormalities and duration since onset of exposure was also very similar. These findings suggest strongly that asbestos exposure characteristic for maintenance work in chemical plants, including indirect ("bystander") exposure, results in risks comparable, although not identical, to those documented for other types of asbestos exposure in other industries and occupations.

The higher prevalence of radiologic pleural abnormalities (pleural fibrosis and/or calcification) than of parenchymal small irregular opacities (interstitial pulmonary fibrosis), the relatively low prevalence of restrictive ventilatory functional impairment, and the paucity of clinical abnormalities all indicate that the risk for disabling asbestosis is less with this type of asbestos exposure. Nevertheless, the risk of lung cancer and mesothelioma is of concern, because accumulated experience indicates that low-level asbestos exposure (indirect occupational, neighborhood, or household exposure) is sufficient to result in a significant risk of developing mesothelioma.[8-10] In the last several years, we have had occasion to observe several cases of mesothelioma in workers employed in chemical, oil-refining, and petrochemical industries. It is possible that an increasing number of such cases may occur, because spectacular growth of these industries has occurred during the last 25–35 years, on the average, the critical latency period.[11]

Summary

In several large groups of workers employed in chemical plants, chest x-ray abnormalities (small irregular opacities and/or pleural changes) of the type known to be induced by asbestos were found in a proportion of those examined. A cross-sectional study of maintenance workers in a large chemical plant was undertaken to evaluate the prevalence of asbestosis; 185 workers were examined. Radiologic evidence of parenchymal interstitial fibrosis was found in 24% of those examined; in 10% of workers, parenchymal fibrosis was the only abnormality. Pleural fibrosis and/or calcification was found in the absence of parenchymal fibrosis in 14% of cases; in another 14% of workers, both parenchymal and pleural abnormalities were detected. The prevalence was significantly higher in those employed 20 or more years.

Pleural abnormalities were more prevalent than were parenchymal changes. The increased risk of lung cancer and mesothelioma remains to be studied.

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